Sea Lamprey
Indicator #18

Overall Assessment

Status: **Fair**
Trend: **Mixed**
Rationale: **Sea lamprey abundances are above target ranges in all lakes except Lake Ontario.**

Lake-by-Lake Assessment

Lake Superior
Status: Fair
Trend: Improving
Rationale: Sea lamprey abundance is above the target range, but has been holding relatively steady since 1999. Sea lamprey abundance has declined beginning in 2005.

Lake Michigan
Status: Poor
Trend: Deteriorating
Rationale: Sea lamprey abundance is above the target range and has been increasing since 2000 with sharp increases each year since 2005.

Lake Huron
Status: Fair
Trend: Unchanging
Rationale: Sea lamprey abundance is above the target range, but has been holding steady.

Lake Erie
Status: Poor
Trend: Unchanging
Rationale: Sea lamprey abundance is above the target range and has been holding steady at pre-control levels since 2005.

Lake Ontario
Status: Good
Trend: Unchanging
Rationale: Sea lamprey abundance is in the target range after three years above the target range. Sea lamprey abundance has been relatively low or in the target range since the mid-1980s.

Purpose

- To estimate adult sea lamprey abundance as an indicator of the status of this invasive species
- To infer the damage caused by sea lamprey to the aquatic ecosystems of the Great Lakes

Ecosystem Objective

This indicator relates to *A Joint Strategic Plan for the Management of Great Lakes Fisheries*: "To secure fish communities, based on foundations of stable self-sustaining stocks, supplemented by judicious plantings of hatchery-reared fish, and provide from these communities an optimum contribution of fish, fishing opportunities and associated benefits to meet needs identified by society for: wholesome food, recreation, cultural heritage, employment and income, and a healthy aquatic ecosystem." In addition, this indicator supports Annex 2 of the GLWQA.

The 1955 *Convention on Great Lakes Fisheries* created the Great Lakes Fishery Commission (GLFC) "to formulate and implement a comprehensive program for the purpose of eradicating or minimizing the sea lamprey populations in the Convention area"

(GLFC 1955). Under *A Joint Strategic Plan for the Management of Great Lakes Fisheries*, all fishery management agencies established fish community objectives for each of the lakes. Fish community objectives call for suppressing sea lamprey populations to levels that cause only insignificant mortality on fish to achieve objectives for lake trout and other members of the fish community (Horns *et al.* 2003, Eshenroder *et al.* 1995, DesJardin *et al.*1995, Ryan *et al.* 2003., Stewart *et al.* 1999).

The GLFC and fishery management agencies have agreed upon target abundance ranges for sea lampreys that will allow achievement of fish community objectives in each lake (Table 1). Targets were derived from estimates of adult sea lamprey abundance and from sea lamprey wounding rates on lake trout (lake trout wounding rates). Suppressing sea lampreys to abundances within the target ranges should result in tolerable mortality on lake trout and other fish species.

Lake	FCO Sea Lamprey Abundance Targets	Target Range (+/- 95% Confidence Interval)
Superior	35,000	18,000
Michigan	58,000	13,000
Huron	74,000	20,000
Erie	3,000	1,000
Ontario	29,000	4,000

Table 1. Sea lamprey abundance targets and ranges.
Source: Great Lakes Fishery Commission.

State of the Ecosystem

Background

The sea lamprey is a non-native species and a lethal parasite of the larger fishes in the Great Lakes (Bergstedt and Schneider 1988, Kitchell 1990), and has caused ecological and economic tragedy in terms of their impact on the Great Lakes fish communities (Smith and Tibbles 1980). The first complete round of stream treatments with the lampricide TFM (as early as 1960 in Lake Superior) successfully suppressed sea lamprey populations to less than 10% of pre-control abundance in all of the Great Lakes. Never-the-less, the sea lamprey continues to be a significant source of mortality for larger fish (Bergstedt and Schneider 1988, Kitchell 1990) and the need for sea lamprey control continues.

Sea lamprey abundance relative to target ranges in each of the lakes is the primary performance indicator of the sea lamprey control program. Lake-wide sea lamprey abundance estimates are calculated by summing the population estimates generated using mark/recapture, trap catch data extrapolation, and the spawner-discharge model (Mullett *et al.* 2003) methods from streams in a given basin. During 2004, each of the lake committees established explicit target ranges for sea lamprey abundance to support the achievement of fish community objectives. These target ranges represent sea lamprey abundance during years when sea lamprey wounding rates on lake trout were tolerable, that is, affecting fewer than 5% annual mortality, and are estimated from historical sea lamprey abundance estimates and available lake trout wounding data from comparable assessment surveys. Abundance estimates and target ranges for each lake are updated during the early fall of each year.

Status of Sea Lamprey

Annual lake-wide sea lamprey abundance estimates with 95% confidence intervals and the target range for each lake are presented in Figure 1. Annual lake trout wounding rate estimates and targets for each lake are presented in Figure 2.

Lake Superior

During the past 20+ years, sea lamprey abundance has fluctuated, but remained at a level less than 10% of peak abundance (Heinrich *et al.* 2003). Sea lamprey abundance was within the target range during the late 1980s and mid-1990s and reached the lowest level of the time series during 1994. Sea lamprey abundance trended upward from the lowest level until 2001, but has been trending downward since then. Sea lamprey abundance has been above the target range since 1999.

Above target sea lamprey abundance is a threat to the fishery of Lake Superior. Wounding rates on fish have also increased and have not shown the same pattern of decrease seen recently in the sea lamprey abundance estimate. The lake trout wounding rate is above target and increasing, and appears to be most dramatic in the western portion of the lake, but has recently declined in Minnesota waters. Estimates in Michigan waters indicate that sea lamprey-induced mortality on lake trout exceeds fishery-induced mortality, but fishery-induced mortality is low in Michigan waters. Fishery objectives for lake trout continue to be met, but lake trout populations are still threatened by sea lamprey as indicated by the above target abundance and lake trout wounding rate.

In response to the above target sea lamprey abundance and lake trout wounding rate, lampricide treatments were increased beginning in 2001. The effects of the increased treatment efforts may have contributed to the recent downward trend in sea lamprey abundance and this trend is expected to continue. Increased treatment effort will continue and the effects will be observed in future sea lamprey abundance and lake trout wounding rate estimates.

Lake Michigan

Sea lamprey abundance is at about 10% of peak levels, but has been trending upward since 1980 (Lavis *et al.* 2003) and has shown sharp increases during 2004, 2006, and 2007. A sharp decrease was observed during 2005. Sea lamprey abundance was in or below the target range until 2000 and has been above the target range since.

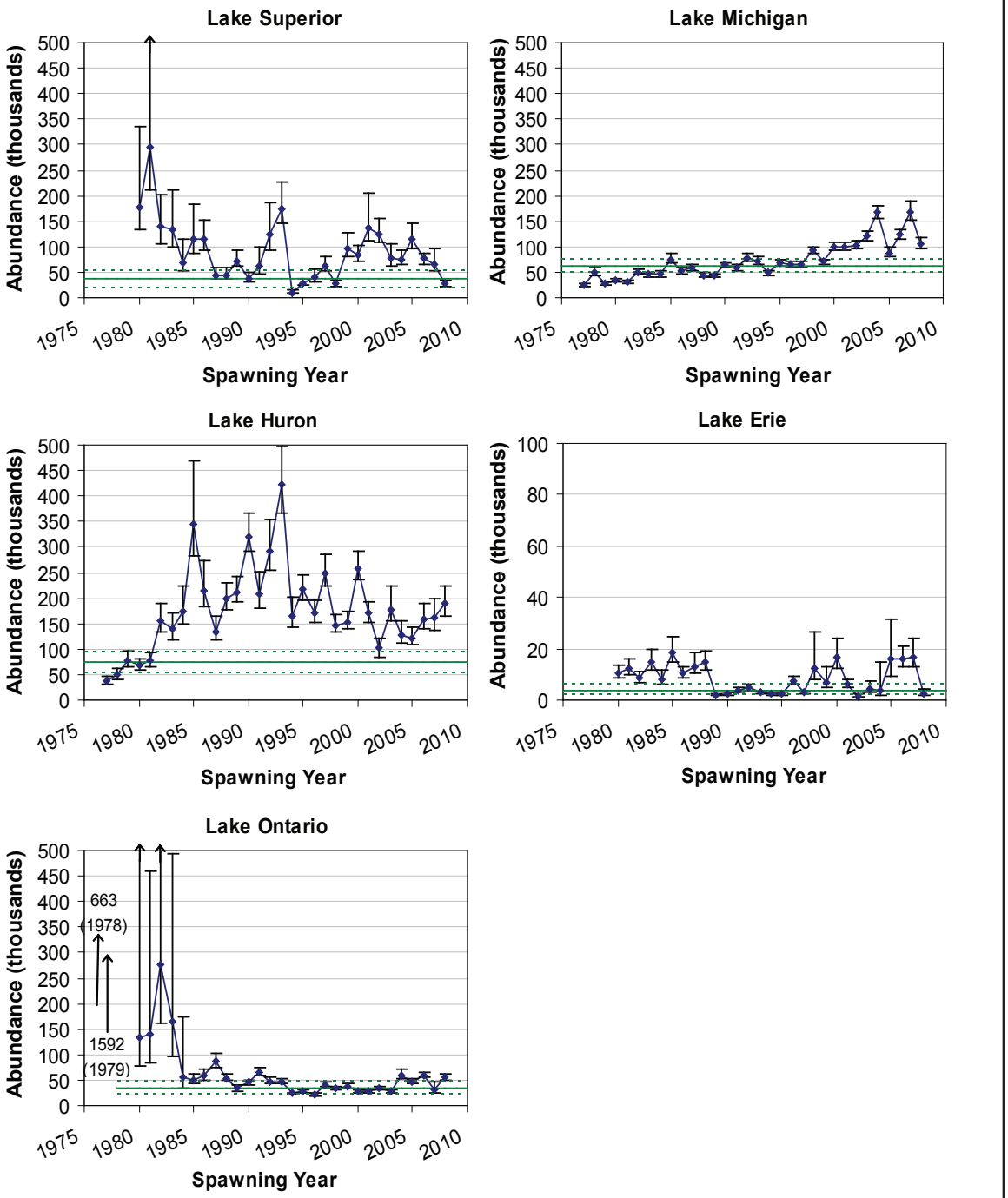

Figure 1. Yearly lake-wide adult sea lamprey abundance estimates with 95% confidence intervals (blue diamonds) presented with the target abundance and range (green horizontal solid and dashed lines) for each lake.
*Note: the scale for Lake Erie is 1/5 that of the lakes.
Source: Great Lakes Fishery Commission.

Above target and increasing sea lamprey abundance is a threat to the fishery of Lake Michigan. The lake trout wounding rate has also shown the same upward trend and is above target, but declining abundance of larger lake trout may be contributing. Increased sea lamprey-induced mortality on lake trout in the northern waters has set lake trout restoration efforts back by a decade. Furthermore, increased mortality is affecting the quota for the commercial fishery to the extent that components of the lake trout management regimen in the consent decree between the tribes, the state, and the federal government are currently suspended. Achievement of lake trout rehabilitation and other fishery objectives will continue to be hampered if sea lamprey abundance and wounding rates on fish remain high and above targets.

Increases in the sea lamprey abundance and lake trout wounding rate during the 1990s were attributed to the St. Marys River. In response, an integrated management approach using lampricides, sterile-male releases, and trapping was initiated in the St. Marys River (Schleen *et al.* 2003) and has reduced the reproductive potential of sea lampreys in the river by about 90%. The continuing upward trend in sea lamprey abundance during the late 1990s and early 2000s indicated there were other significant sources of sea lampreys. Lampricide treatments on Lake Michigan increased during 2001 and included the treatment of newly discovered populations in lentic areas and the Manistique River, a large system where the deterioration of a dam near the river mouth allowed sea lampreys access to hundreds of kilometers of habitat. The 2003 sea lamprey abundance and lake trout wounding rate estimates did not show any decreases as a result of the increased treatments during 2001, however, the sharp decrease in sea lamprey abundance observed during 2005 was most likely associated with the 2003 treatment of the

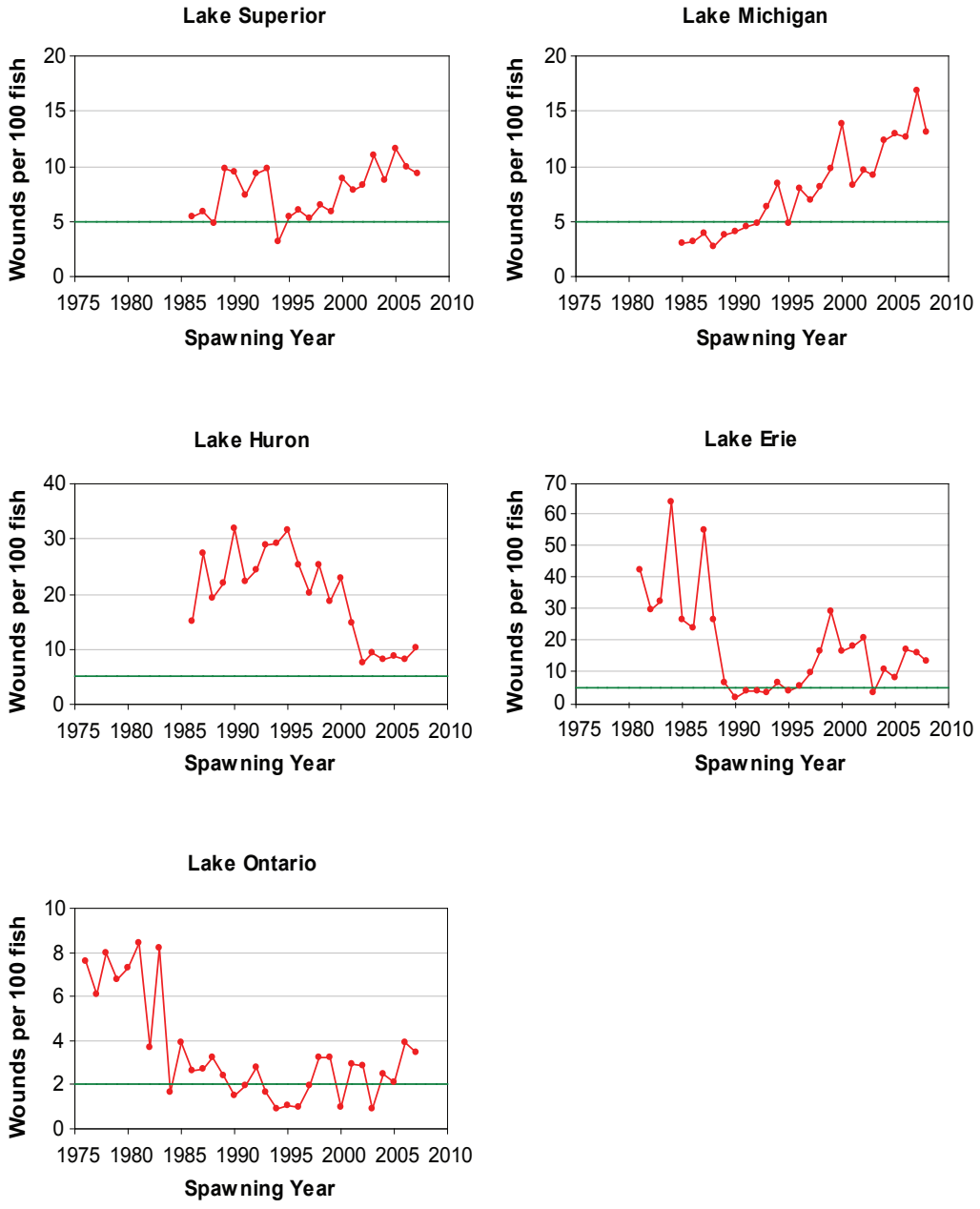

Figure 2. Yearly lake trout wounding rate estimates (red circles) presented with the wounding rate target (green horizontal line) for each lake.
*Note: Lake Ontario reports A1 wounds only (notice different scale); all other lakes report A1-3 wounds.
Source: Great Lakes Fishery Commission.

Manistique River. Increased treatment efforts during recent years, including additional treatments of the Manistique River, have not produced decreases in sea lamprey abundance or the lake trout wounding rate. Other potential sources of sea lampreys are being assessed and increased treatment efforts will continue with the effects to be observed in future sea lamprey abundance and lake trout wounding rate estimates.

Lake Huron

During the past 20+ years, sea lamprey abundance has fluctuated, but remained at a level less than 10% of peak abundance (Morse *et al.* 2003). During the early 1980s, sea lamprey abundance increased from the target range, particularly in the northern portion of the lake, peaking during 1993. Sea lamprey abundance is currently above the target range and has been since 1981.

Above target sea lamprey abundance is a threat to the fishery of Lake Huron. Through the 1990s, there were more sea lampreys in Lake Huron than all the other lakes combined and fishery objectives were not being achieved. Sea lamprey-induced mortality was so severe that during 1995 lake trout restoration efforts were suspended in the northern portion of the lake. There has been a significant reduction in the lake trout wounding rate since the implementation of the integrated management approach on the St. Marys River (lampricide treatment, sterile-male release, and trapping; Schleen *et al.* 2003), which reduced the reproductive potential of sea lampreys in the river by about 90%. Although the lake trout wounding rate is still above target it remains at a low level, lake trout restoration efforts have been continued, and populations are increasing and showing signs of natural reproduction. Never-the-less, lake trout restoration efforts will continue to be hampered if sea lamprey abundance and the lake trout wounding rate remain above targets.

During the 1990s, the St. Marys River was identified as the major source of sea lampreys in Lake Huron, but the size of the river prohibited traditional treatment with the lampricide TFM. In the integrated management approach (lampricide treatment, sterile-male release, and trapping; Schleen *et al.* 2003), a new formulation of a bottom-release lampricide was used in place of TFM with the first full round of treatments happening during 1999. As predicted, the integrated management approach significantly lowered sea lamprey abundance and the lake trout wounding rate. Never-the-less, sea lamprey abundance has been considerably variable since 2001 (the year in which the effects of the 1999 integrated management approach were first observed). Lampricide spot treatments on the St. Marys River have continued in areas with high densities of larvae and treatment efforts have been increased in other areas around the lake during recent years. The effects of additional treatment efforts will be observed during future sea lamprey abundance and lake trout wounding rate estimates.

Lake Erie

Following the completion of the first full round of stream treatments in 1987, sea lamprey abundance plummeted (Sullivan *et al.* 2003) and remained in the target range during 1989 to 1997. Sea lamprey abundance increased briefly during 1998 to 2000, but returned to within the target range during 2001 to 2004. Sea lamprey abundance has been above the target range and has returned to pre-control levels since 2005.

Above target and high sea lamprey abundance is a threat to the fishery of Lake Erie. After the initial stream treatments, the lake trout wounding rate declined and lake trout survival increased to a level sufficient to meet the rehabilitation objectives in the eastern basin. During 1997 to 2002, the lake trout wounding rate increased to and remained at a level that threatened lake trout restoration. The lake trout wounding rate fell below the target during 2003, but has trended upward since and is currently above target. Reductions in lake trout stocking since 1996 may be affecting lake trout abundance, and hence, the lake trout wounding rate. Wounding rates on other fish species have also been increasing. Achievement of lake trout rehabilitation and other fishery objectives will continue to be hampered if sea lamprey abundance and wounding rates on fish remain high and above targets.

The initial stream treatments conducted during 1987 reduced sea lamprey abundance and the lake trout wounding rate to targets. In response to recent (since 2005) increases in sea lamprey abundance to high levels, and above target and increasing lake trout wounding rates, treatment efforts were increased during 2006. Additionally, an aggressive and experimental whole-lake treatment strategy in which all sea lamprey-producing streams are treated in back-to-back years commenced during 2008. The effects of the increased treatment effort and whole-lake treatment experiment will be observed in sea lamprey abundance and lake trout wounding rate estimates during 2008 and beyond.

Lake Ontario

Sea lamprey abundance was greatly reduced following the completion of important lampricide treatments during the 1980s and steadily declined from the mid 1980s to 2003 (Larson *et al.* 2003). Sea lamprey abundance was still relatively low during 2004 to 2006, but was above the target range. Sea lamprey abundance returned to within the target range during 2007 and has been in or near the target range since the mid-1980s.

Although sea lamprey abundance is within the target range, the lake trout wounding rate has not decreased and has been holding steady around the target since the mid-1980s. The lake trout wounding rate has been above target since 2004 and has been high in waters off the mouth of the Niagara River. Changing strain composition of lake trout and reduced abundance of larger fish may be affecting lake trout wounding rates. Achievement of lake trout rehabilitation and other fishery objectives will continue to be hampered if the lake trout wounding rate remains above target or if sea lamprey abundance increases.

The treatment of important streams during the 1980s, including the Black and Oswego systems, precipitated a significant decline in sea lamprey abundance. Subsequent lampricide treatments caused a steady decline in sea lamprey abundance, which has been in or near the target range since the mid-1980s. Lampricide treatments are continuing and sea lamprey abundance and the lake trout wounding rate are expected to remain close to targets during the future.

Pressures

Sea lamprey control in the Great Lakes has successfully reduced sea lamprey abundance from peak levels by about 90%. Sea lampreys, however, still remain a significant source of mortality on the larger fishes of the Great Lakes and a road block to achieving critical fishery objectives. Increasing sea lamprey abundance in Lake Erie demonstrates how short lapses in control can result in rapid increases in abundance, and that continued effective stream treatments are necessary to overcome the reproductive potential of this invasive species. In addition, the potential for sea lamprey to colonize new locations is increased with improved water quality and removal of dams. For example, the failure of the Manistique River dam to block sea lampreys, and the subsequent sea lamprey production from this river, has contributed to the increase in sea lamprey abundance in Lake Michigan. Continuing the search for new or unidentified sources of sea lampreys is critical for sea lamprey control. Any new or unidentified sources of sea lampreys will require some form of control to help attain abundances within the target range in each lake.

As fish communities recover from the effects of sea lamprey predation, there is evidence that sea lamprey populations will benefit from the increase in prey availability. Facilitated through what are called compensatory mechanisms, more sea lampreys may survive due to the increase in prey availability, thus precipitating an increase in reproductive potential and recruitment (i.e. more sea lampreys may be available to prey on fish). To combat potential compensatory responses, significant additional control efforts, like the integrated management approach on the St. Marys River, the experimental whole-lake treatment strategy on Lake Erie, and the implementation or development of alternative sea lamprey control strategies (e.g. barriers, pheromones, genetic controls, etc.) will be necessary to further suppress sea lamprey abundances to target ranges.

The GLFC has a goal of reducing reliance on lampricides and increasing efforts to integrate other control techniques, such as the sterile-male-release technique or the installation of barriers to stop the upstream migration of adults. Pheromones that affect migration and mating have been discovered and offer exciting potential as new alternative controls. The use of alternative controls is consistent with sound practices of integrated pest management, but can put additional pressures on the ecosystem such as limiting the passage of fish upstream of barriers. Care must be taken in applying new alternatives or in reducing lampricide use to not allow sea lamprey abundances to increase.

Management Implications

The GLFC has increased stream treatments and lampricide applications in response to increasing sea lamprey abundance estimates during recent years (see status of sea lampreys for each lake above for details). The GLFC has targeted these additional treatments to reduce sea lamprey abundance and lake trout wounding rate to targets. The GLFC continues to focus on research and development of alternative control strategies. Computer models, driven by empirical data, are being used to best allocate treatment resources, and research is being conducted to better understand and manage the variability in sea lamprey populations.

Comments from the author(s)

Increases in lampricide treatments are predicted to reduce sea lamprey abundances to target ranges. The effects of increased treatments will be observed in this indicator two years after they occur. Discrepancies among abundance estimates of different

life-history stages need to be resolved. Efforts to identify all sources of sea lampreys also need to continue. In addition, research to better understand sea lamprey/prey interactions, the population dynamics of sea lamprey that survive treatment, and refinement of and research into alternative control methods are all keys to maintaining sea lamprey abundances in target ranges.

Assessing Data Quality

Data Characteristics	Strongly Agree	Agree	Neutral or Unknown	Disagree	Strongly Disagree	Not Applicable
1. Data are documented, validated, or quality-assured by a recognized agency or organization	X					
2. Data are traceable to original sources	X					
3. The source of the data is a known, reliable and respected generator of data	X					
4. Geographic coverage and scale of data are appropriate to the Great Lakes basin	X					
5. Data obtained from sources within the U.S. are comparable to those from Canada	X					
6. Uncertainty and variability in the data are documented and within acceptable limits for this indicator report	X					
Clarifying Notes:						

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Michael J. Siefkes, Great Lakes Fishery Commission, Ann Arbor, MI (2008)

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